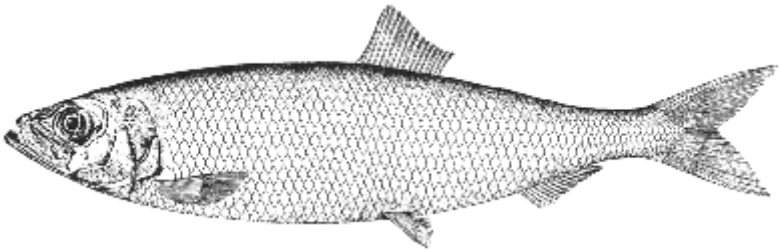
FEAS Survey Series: Industry Survey/01/2016

Atlantic Herring in 6aS/7b, c
Industry Acoustic Survey Cruise Report

28 November – 07 December, 2016



Herring (*Clupea harengus*) Linnaeus 1758. Drawing by H. L. Todd.

MFV Atlantic Challenge D642

Michael O'Malley, Maurice Clarke, Ciaran O'Donnell, Ian Murphy

The Marine Institute, Fisheries Ecosystems Advisory Services

Rinville, Oranmore, Co. Galway

Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
Cómhaoinithe ag Rialtas na hÉireann agus ag an Aontas Eorpach

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

Table of Contents

1. Introduction

Following the ICES benchmark workshop on Atlantic herring *Clupea harengus* in 6aN, 6aS and 7b, c (ICES 2015a), the individual stock assessments for both stocks have been combined into one assessment encompassing both stocks. ICES still considers two separate stocks exist; 6aN and 6aS/7b, c. The main reason for the merging has been that the catches of mixed aggregations in the commercial fishery and in the summer acoustic survey could not be separated into the different stock components. The consequence of this has been a zero TAC for herring in these areas for 2016 and 2017 (ICES 2015b). In its autumn 2015 plenary report, the Scientific, Technical and Economic Committee for Fisheries (STECF PLEN 15-03, 2015), noted that from a stock assessment perspective, it would be beneficial to allow small catches in both management areas in the form of a monitoring TAC, to maintain an uninterrupted time series of fishery-dependent catch data from both stocks (Campbell 2016). On the request of industry, part of the monitoring TAC was set aside in 2016 to conduct acoustic/trawl surveys in both 6aN and 6aS/7b, c (ICES 2016). In August/September 2016 an acoustic/trawl industry survey was carried out in 6aN on spawning aggregations on the dominant autumn spawning herring in that area. A similar effort was completed in 6aS and 7b, c during November/December on the more dominant winter spawning herring in this area. Spawning is known to occur outside these times in both areas, but the timing for both surveys was considered to be appropriate during the survey planning process with the resources available. This report considers the survey conducted in 6aS/7b, c only. Results from both surveys were presented to the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) in January 2017 and the data and results are documented there also.

Survey objectives

The survey is part of a collaborative partnership between Ireland, The Netherlands and UK (Scotland) that aims to improve understanding of the individual stock components of herring in 6a and 7b, c. Also, the work continues the time-series of data on the spawning components of herring stocks in 6aN and 6aS and 7b, c. The Marine Institute Industry collaboration survey collected acoustic information and echo trace validation samples from pre-spawning and spawning aggregations of herring in 6aS and 7b, c in Nov/Dec 2016. Samples from spawning fish may also be used for morphometric studies, ageing, genetic analyses and otolith microstructure, if required outside of the fishery in 6aS.

The overall survey objectives are:

- Collect integrated and calibrated acoustic data on herring aggregations within the pre-determined survey area
- Collect acoustic data and detailed biological information (length, weight, sex, maturity, age) of herring to allow estimation of the size of spawning components of herring in 6aS and 7b, c as well as to identify echotrace to species.
- Determine the extent and behaviour of herring aggregations within the survey area to aid the design of future surveys
- Collect morphometric and genetic data on spawning fish to distinguish whether the 6aS and 7b, c stocks can be differentiated from the stocks in 6aN
- Determine the biomass and abundance of herring by age within the survey area
- Collect integrated and calibrated acoustic data on horse mackerel *Trachurus trachurus* aggregations within the pre-determined survey area
- Collect biological samples from directed trawling on insonified echotraces to determine size structure of horse mackerel

Area of operation and survey design

The survey collected acoustic information and samples from pre-spawning aggregations of herring in 6aS and 7b, c. Known spawning areas are shown in Figure 1. The survey objective in 2016 was to cover the area in 6aS and 7b, c focussed on areas where herring are known to be either spawning or in pre-spawning migrations during this time of the year. Spawning time in this area is variable, generally between October and February (Table 1).

Survey Plan

The survey starting point was off the Inishowen Peninsula north of Donegal to the east of Inishtrahull Island (55˚24N and 7˚0W, Figure 2). Transects were generally north/south, and the survey progressed from east to west. The survey area coverage was based on the predicted distribution of herring in this area during this time. In total 1,649nmi of cruise track was completed using 41 transects and related to a total area coverage of approximately 4,500 nmi². Transect spacing was set at 3nmi. Coverage extended from inshore coastal areas to the 100 m contour in the west and north. A mini survey was carried out in Lough Swilly using a zig-zag design due to the shallow water depths found there. The additional survey track in Lough Swilly was designed using the deepest part of the channel as the centreline for the strata area. 500m either side of this centre line was delineated as the boundary area; zig-zag transects were then placed within the strata boundaries. An elementary distance sampling unit (EDSU) of 1nmi was used during the analysis throughout the survey data. The survey was carried out over 24 hours each day.

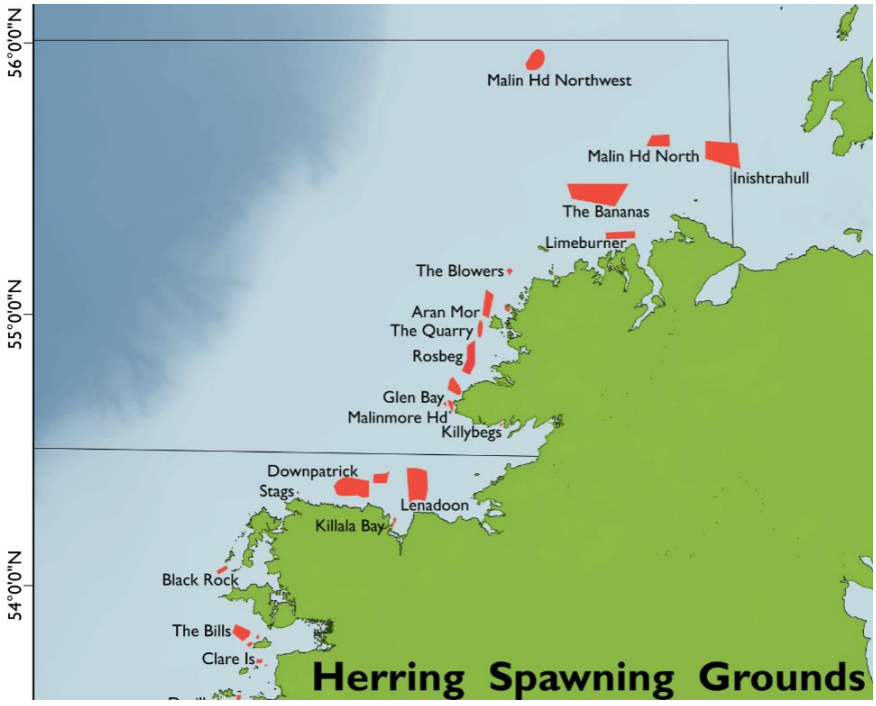


Figure 1. 6aS/7bc industry acoustic survey in 2016: herring spawning grounds in 6aS and 7b, c (from O'Sullivan, 2013).

Table 1: 6aS/7bc industry acoustic survey in 2016: Spawning areas, spawning grounds and spawning beds in 6aS and 7b, c. Area (km^2) and depth (m) refer to individual spawning beds (from O'Sullivan, 2013).

Spawning Area	Spawning Ground	Spawning Bed	Depth (m)	Area (Sq Km)	Activity
North Donegal	Malin Head	Inishtrahull	45	121.58	November
		Malin Head North	90	39.06	November
	Limeburner	Limeburner	30	33.28	November
		The Bananas	58	169.17	Nov and Feb
	Tory	Malin Head Northwest	70-90	47.42	Nov and Feb
West Donegal	The Blowers	The Blowers	30	3.96	Oct/Nov
		Stags	20	0.89	Nov/Dec
	Aran Mor	Aran Mor 1	43	32.35	Oct/Nov
		The Quarry	70-80	11.84	October
	Rosbeg 1	Rosbeg 1.1	32-36	0.13	Oct/Nov
	Rosbeg 2	Rosbeg 2.1	43	44.06	October
	Glen Head	Glen Bay	32-36	24.17	Nov/Dec
		Malinmore Head 1	18	6.31	November
		Malinmore Head 2	90	1.59	Jan/Feb
Donegal Bay	Killybegs	Killybegs 1	20	1.01	Dec/Jan
	Lennadoon	Lennadoon 1	32-42	101.92	Jan/Feb
		Killala Bay	25	3.05	January
	Downpatrick	Downpatrick West	32	23.66	November
		Downpatrick/Ceide Fields	34-45	97.05	Dec/Jan
Mayo	The Stags	The Stags 1	36	0.89	November
	Blackrock	Blackrock 1	36	7.74	Oct/Nov
	Clare Island	The Bills	36	29.83	November
		Clare Island 1	32	3.07	Oct/Nov
		Clare Island 2	36	1.58	Oct/Nov
		South Clare Island 1	45	3.71	December
		South Clare Island 2	~40-45	2.01	Nov/Dec
	Lecky Rock	Davillaun/Lecky Rock	20	3.63	Sept/Oct

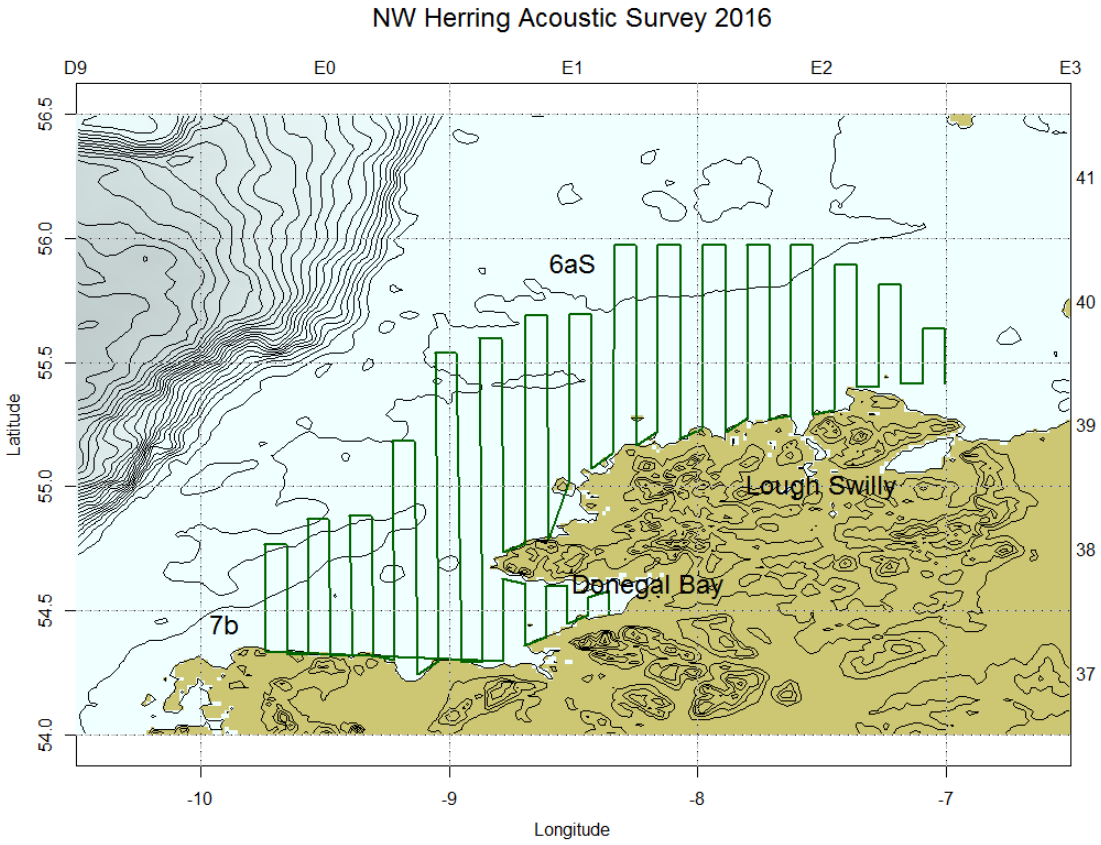


Figure 2. 6aS/7bc industry acoustic survey in 2016: acoustic survey area and transects for 6aS/7b, c in 2016. The survey in 2016 was exclusively in Irish waters, approximately up to the 56˚N line in the north and 7˚W line in the east. To the west, the survey was bounded approximately by the 100m depth contour. The total transect length was 1,649nmi (start 55˚24N and 7˚0W, progress west) with 3nmi separation between transects.

Scientific Personnel

Organisation	Name	Capacity
FEAS	Michael O'Malley	Acoustics (Chief Scientist)
FEAS	Ian Murphy	Analyst
PFA	Raoul Kleppe	Analyst
Contractor	Frankie McDaid	Analyst

2. Materials and Methods

Sampling protocols and equipment specifications

Acoustic data were collected using a SIMRAD EK60 scientific echosounder topside unit. Simrad ES-38B (38 kHz) and ES-120 (120 kHz) split-beam transducers mounted on the vessels hull were calibrated before the survey. GPS feeds were obtained from the vessel, and the whole topside system was powered by an un-interrupted power source (UPS). Vessel details and set up are provided in Appendix 4.

Where possible cruising speed was maintained at 10kts. Cruising speed was largely determined by the weather with concern for the effects on the quality of acoustic data.

Calibration of acoustic equipment

The EK60 was calibrated at the pier in Killybegs prior to the start of the survey in calm conditions. The calibration was carried out using standard methodology as described by Foote *et al.* (1987). Results of the calibration are presented in Appendix 1 and 2.

Figure 3. 6aS/7bc industry acoustic survey in 2016: hull mounted echosounders (Atlantic Challenge D642) were calibrated at the new pier in Killybegs, Co. Donegal.

Standard LOBE calibration (SIMRAD 2003; Demer et al 2015) was carried out on the Atlantic Challenge on the evening of 28/11/2016 and the morning of 29/11/2016. The successful calibration was made possible by good conditions in the deep water at the new pier (~20m depth at slack high). There was minimal interference from biota in the water column.

Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. Acoustic settings are shown in Table 2. The “RAW files” were logged via a continuous Ethernet connection as “EK5” files to a laptop and a HDD hard drive as a backup. Sonar Data’s Myriax Echoview® Live viewer (V6.1) was used to display echograms in real time and to allow the scientists to scroll through noting the locations and depths of target schools to a log file. A member of the scientific crew monitored the equipment continually. Time and location were recorded for each transect start/end position within each stratum. This log was also used to monitor “off track events” such as fishing operations. Acoustic raw data files were backed up every 24 hrs

Acoustic settings

Table 2. 6aS/7bc industry acoustic survey in 2016: Acoustic settings

Area	Vessel	Transducer **and** frequency	Echosounder	Power**/** **p**ulse duration **p**ing interval	Environment	Calibration **l**ocation/ date	Survey area changes
6aS/7bc	Atlantic Challenge	Hull mounted split beam ES38B (38kHz) Hull mounted split beam ES120B (120kHz)	SIMRAD EK60	Power = 2000W (38kHz); 500W (120kHz) Pulse duration = 1.024ms Ping interval = max	Temp = 10˚C, Salinity = 34ppt, Sound speed = 1488.6 m/s	New Pier, Killybegs, Co. Donegal 28th November 2016	Additional transects in Lough Swilly. Additional searching conducted with the sonar in the Tory Bank area.

Echogram scrutinisation

Scrutinising echograms involves identifying fish marks and assigning them to species, and ensuring that any non-fish acoustic signals are not included as fish (e.g. bottom signals). Assigning fish marks to species is a heuristic process that relies upon (i) evidence from the targeted hauls made during the survey, (ii) prior experience of 'experts' (fishermen and acoustic scientists) based on their knowledge of what was caught when certain types of fish marks were fished upon in the area in previous surveys occurring around the same time, (iii) multi-frequency analysis and (iv) knowledge of fish behavior.
While it's impossible to be 100% confident when assigning fish marks to species, following agreed guidelines for classification (e.g. ICES 2015c) of marks greatly improves the consistency in the way that acoustic data from different surveys are scrutinized, and hence in the quality and comparability of the biomass estimates.
Acoustic fish marks were classified in to the following categories (See examples in Appendix 3a, b and c):

1. Herring – confident that the marks were herring based on either evidence from a targeted haul or proximity and similarity to other schools known to be herring.
2. Unclassified – confident that the marks were not herring based on either evidence from a targeted haul or proximity and similarity to other schools known to not to be herring, or characteristic atypical of herring schools.
3. Horse mackerel *Trachurus trachurus* – confident that the marks were horse mackerel based on either evidence from a targeted haul or proximity and similarity to other schools known to be horse mackerel. Horse mackerel were observed throughout 6aS/7bc. Marks were verified with trawls in the area.

The decision to fish on particular echotraces was based on both the distance from other fishing operations on similar schools, and on the difference between recently observed echotraces and others previously sampled.

Echograms were processed and subsequently analysed as separate transects. Off track events, such as data collected during fishing, transiting to the start point, and off-track searching using sonar were excluded from further analysis. Echo integration was performed on regions which were defined by enclosing selected parts of the echogram that corresponded to one of the three categories above. The echograms were generally analysed and echo-integrals calculated, at a threshold of -70 dB. How strongly the acoustic marks are displayed on the screen (backscatter threshold) can have a bearing on the interpreters classification of the acoustic marks and their selection using school detection algorithms. While it is desirable to be consistent in the setting of this parameter, in practice the setting is determined largely by the need to filter out fish schools from other acoustic signals that create noisy backscatter data.

Acoustic survey protocols

The survey was continuous over 24hours due to the limited daylight in December and scale of coverage planned. Survey speed was 10 knots, reducing as needed depending on sea conditions. To maximise the quality of data recorded, FV Atlantic Challenge took on board ballast water to aid stability of the vessel and minimise cavitation and air bubbles interfering with echoes under the transducers. In addition, all other acoustic equipment was turned off to eliminate interference with the EK60. Only during fishing operations and off-track searching were other acoustic instruments used. Survey log sheets were used to record all transect data, including transect position, haul position and other events taking place on and off transect.

Fishing operations for scientific samples

During the acoustic surveys, selected fish marks were targeted with a fishing operation (Figure 4) to capture fish for the purposes of:

(i) Confirming the species identity of acoustic marks, particularly those suspected to be herring or to confirm that they were definitely not herring
(ii) Collecting samples for biological analysis

The fishing operations were directed to take a catch of the smallest possible size sufficient for biological sampling.

The vessel was granted a derogation to discard fish that were not retained for biological sampling and to retain any catches of herring, up to the maximum specified quota taken either during or outside the survey period.

A single pelagic midwater trawl with the dimensions of 300m in total length was used during the survey. The horizontal net spread averaged 90m from wing to wing. The net was fished with a vertical mouth opening averaging 35m. The net opening during fishing was observed using a cable linked SIMRAD FS 900 netsonde (200 kHz). The net was fitted with catch and tunnel sensors to monitor the catch entering the trawl.

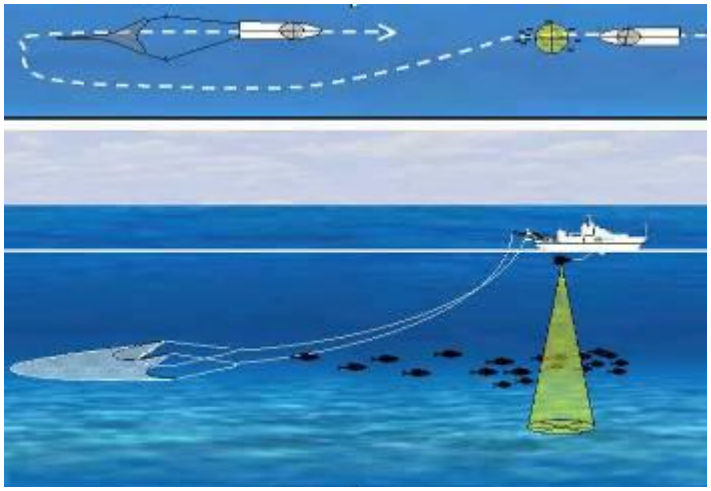


Figure 4. 6aS/7bc industry acoustic survey in 2016: schematic description of fishing operation to collect a biological catch sample during an acoustic survey.

Haul information

Haul data were recorded using the same template for all surveys (one sheet per haul). Information was recorded on the date, time, fishing position, depth, gear, catch composition, total weight of catch and weight of the sub sample taken for length frequency and biological sampling. For hauls used in helping to scrutinize the acoustic data, additional information was recorded on the sheets to show how the acoustic traces looked on the netsonde and

echosounder. A screen grab from the echosounder was also taken of each mark. In the comments box, comments were made on whether or not the targeted schools were captured by the trawl, and any other relevant information, including whether herring was spawning (based on "running" eggs and milt upon capture).

Biological sampling

All components of the catch were sorted to species level and weight by species was recorded. Length, weight, sex and maturity data were recorded for individual herring in a random 100 fish sample from each trawl haul. In addition a further 100 length/weight and 100 fish length frequency measurements were taken from each haul. No aging was carried out onboard and samples were analysed back in the lab. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul. For species other than herring, length and weight measurements were taken for 100 individuals per trawl.

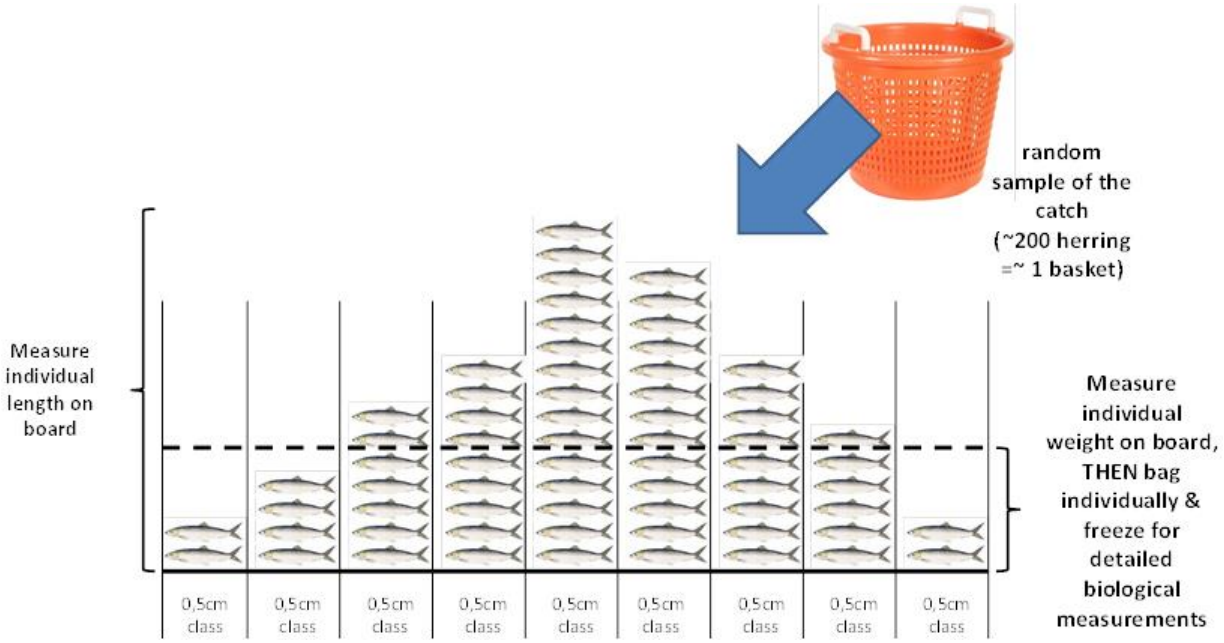


Figure 5. 6aS/7bc industry acoustic survey in 2016: Illustration of the required catch sampling procedure.

Length measurements

The length of all the herring in the subsample was measured and recorded to the nearest half centimetre below. This data is used to determine a length frequency distribution of the catch and subsequently to apply an age-disaggregated estimate of biomass. Five fish from each half centimetre length class were saved for additional biological measures.

Otoliths for age determination

Taking the 5 fish in each length class, each measured fish was assigned an ID number and the otoliths extracted for age determination at the lab.

Standard procedures for age determination from the growth rings on the otoliths (ear bones) of herring were used to determine the age of fish sampled. This age data was used to create an age-length key (Figure 13).

Analysis methods - age disaggregated abundance estimate

The recordings of area back scattering strength (nautical area backscattering coefficient – NASC [m^2/nmi^2]) per nautical mile were averaged over a one nautical mile EDSU (Elementary distance sampling unit), and the allocation of NASC values to herring schools and other acoustic targets was based mainly on the composition of the trawl catches, the appearance of the echotraces, multi-frequency techniques, reports from the fleet in the same area, and experience.

The following TS-length relationships used were those recommended in the manual for international acoustic surveys (ICES 2015d):

Herring	TS = $20\log_{10}L$ – 71.2 dB per individual (L = length in cm)
Horse mackerel	TS = $20\log_{10}L$ – 67.5 dB per individual (L = length in cm)

The process for estimating abundance and biomass of herring from the acoustic data is shown in its component parts in Figure 6.

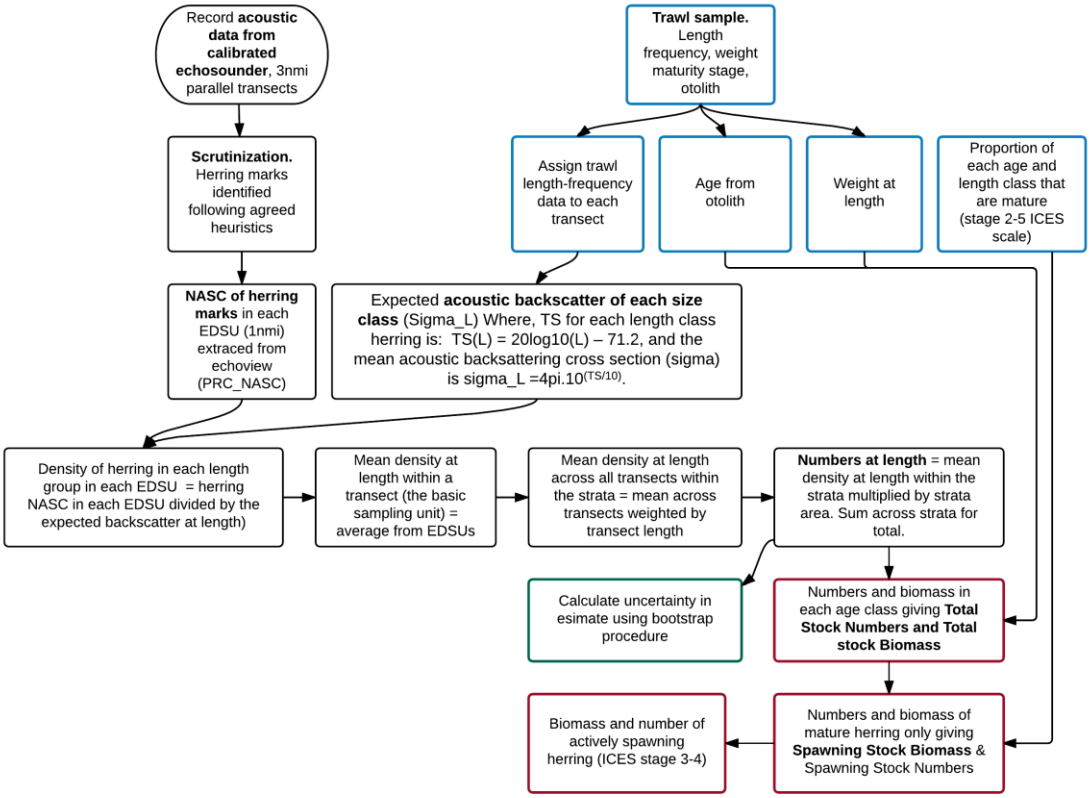


Figure 6. 6aS/7bc industry acoustic survey in 2016: Flow diagram of the analysis methods to estimate abundance and biomass. Blue boxes – biological data; black boxes – treatment of acoustic data; red boxes- derived abundances indices; green box – uncertainty estimates

The StoX software (http://www.imr.no/forskning/prosjekter/stox/nb-no) was used to calculate the age disaggregated acoustic abundance and biomass estimates. StoX is an open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application built in Java for easy sharing and further development in cooperation with other institutes, and is now routinely used to derive abundance estimates from WGIPS coordinated surveys. Documentation and user guides are available from the website. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

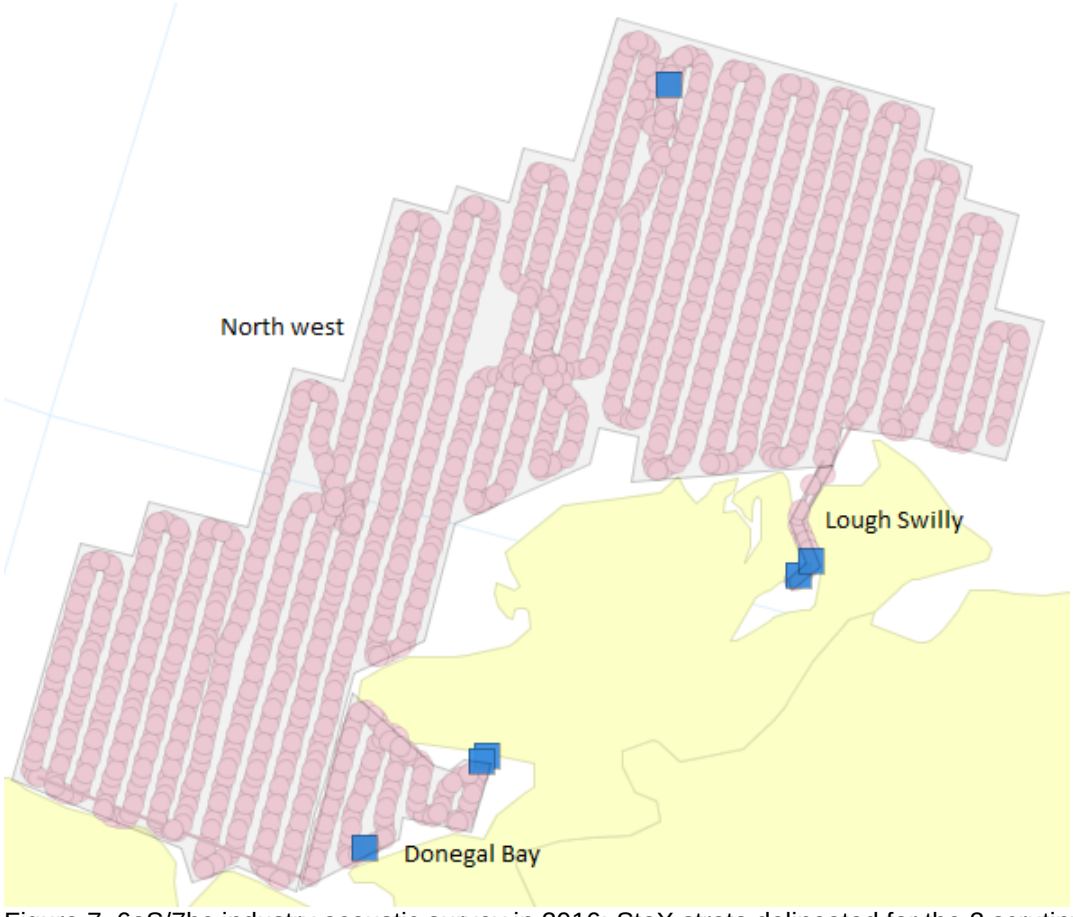


Figure 7. 6aS/7bc industry acoustic survey in 2016: StoX strata delineated for the 3 scrutiny areas (Lough Swilly, Northwest, and Donegal Bay). The 6 haul/sample stations where herring were obtained for length frequency analysis are also shown.

Following scrutinisation of the echograms, the EDSU (1nmi) specific Nautical Area Scattering Coefficient (NASC - the area backscattering coefficient for a particular integration region in areal units (m^2/nmi^2)) assigned to herring marks (represented as PRC_NASC in Echoview) is exported. The calculation of age disaggregated abundance was as follows:

1. **Assigning herring length data from trawls to acoustic transects.** For each transect within each survey strata (where each of the 3 areas surveyed represents a strata in 6aS/7bc [Figure 7]), the length distribution of herring associated with each transect was determined as the un-weighted mean of all trawls allocated to the respective transects.
2. **Expected backscattering cross section of herring in each length group.** The mean acoustic backscattering cross-section "sigma" (σ_{bs}) for each length group of herring was calculated from the length frequency data assigned to each transect using the target strength-length relationships for herring recommended by the ICES Working Group on International Pelagic Surveys (ICES 2015d). The target strength (TS) relationship used to calculate the mean acoustic backscattering cross-sections for herring is:

$$TS = 20\log10\,(L) - 71.2 \qquad \text{[at 38 kHz]}$$

The mean acoustic backscattering cross section is:

$$\sigma_{bs} = 10^{(TS/10)}$$

3. **The average density of herring in each length class on a single transect** is calculated by dividing the NASC within each 1nmi EDSU of each transect by the length-specific σ_{bs} (acoustic backscatter cross-section) assigned to each transect. This is then averaging over the EDSUs.
4. **Numbers of herring in a single stratum & total numbers.** For each length group, a weighted average (weighted by transect length) of the mean density of herring in each transect is multiplied by the area of the stratum. Total numbers at length is the sum for each stratum.
5. **The numbers and biomass per age & maturity class.** Trawl data on the relationship between length, age and maturity stage were used to partition the numbers at length in to estimates of numbers and biomass in each age class and maturity stage. The 9 point maturity stage classification was used.
6. **Estimate of the relative sampling error.** Within StoX a bootstrap procedure was used to estimate the coefficient of variance (CV) of the estimate of numbers at length. The procedure randomly selects transects within a stratum with replacement, and for each selected transect, the trawl stations which are assigned for the selected transect are randomly sampled with replacement. Thereafter, each run follows the same estimation procedure as used in StoX and described above.
7. **How estimates from the intensely surveyed (mini grids) were included.** In Lough Swilly, a zig-zag transect pattern was executed, therefore this area was treated as a separate strata in StoX (Figure 7). The boundaries of the strata were delineated approximately 500m either side of the centre line of the deepest part of the Lough Swilly channel in approximately 10 – 20m water depth. The zig-zag transect lines were laid out within the boundaries set out.

Acoustic data were saved on hard-drives at sea and uploaded to network facilities back at the Marine Institute, Ireland. The acoustic metadata and cleaned post-processed EV files will be stored at the Marine Institute following established procedures. Estimates of abundance made from the surveys will be stored in the ICES WGIPS acoustic database.

3. Results

Acoustic and biological

After calibration of the hull mounted transducers at the pier in Killybegs, 1,649nmi of transects were completed successfully. A total of three hauls were completed, however, only one contained herring (Figure 8, Table 3). In some areas where marks of herring were observed, the vessel was unable to fish due to the shallow water depth (e.g. <20m in Lough Swilly) and size of gear available. The monitoring fishery was being conducted at the same time as the survey, on smaller boats in the same areas. Biological samples from some of these vessels were used to augment the sample from the survey. Samples were taken from boats fishing in Lough Swilly and Donegal Bay as close spatially and temporally as possible to the survey in these areas (Table 4).

Table 3. 6aS/7bc industry acoustic survey in 2016: total weight (kg) of sub-samples of the catch by species in hauls conducted.

Haul No	Species name	Total sub-sample weight (kg)
1	*Clupea Harengus*	42.44
1	*Maurolicus muelleri*	0.008
1	*Melanogrammus aglefinus*	6.37
1	*Merlangus merlangus*	11.3
1	*Micromesistius poutassou*	3.76
1	*Scomberus scombrus*	28
1	*Trachurus trachurus*	0.8
1	*Trisopterus esmarkii*	0.174
1	*Trisopterus minutus*	0.056
2	*Aurelia sp.*	0.034
2	*Merlangus merlangus*	0.344
2	*Scomberus scombrus*	16.84
2	*Trachurus trachurus*	138.96
3	*Melanogrammus aglefinus*	0.59
3	*Scomberus scombrus*	22.254
3	*Trachurus trachurus*	129.29
3	*Trisopterus esmarkii*	0.014

Table 4. 6aS/7bc industry acoustic survey in 2016: biological sampling summary statistics from survey hauls (1 - 3) and samples from the monitoring fishery (4 – 10).

Haul/Station	Date	Location	Fish (measured/lengths)		Ages/maturity/sex
			Clupea Harengus	*Trachurus trachurus*	
1	2/12/2016	Offshore	200		50
2	3/12/2016	Offshore		160	0
3	4/12/2016	Offshore		243	0
4	29/11/2016	Lough Swilly	337		69
5	16/11/2016	Lough Swilly	268		64
8	21/11/2016	Donegal Bay	248		75
9	21/11/2016	Donegal Bay	183		48
10	13/12/2016	Donegal Bay	250		56

The location of survey hauls and samples from the fishery is shown in Figure 8. The fishery in 6aS/7bc began in mid-November and continued throughout the survey period. Most of the fishing activity, particularly in late November/early December was inshore in shallow water. Very strong marks (> 1nmi long and ~16m deep) were evident in Lough Swilly (appendix 3a), also an area where smaller boats in the fishery were concentrating effort. There was a series of strong herring marks in Donegal Bay in a discreet area (appendix 3b). There were some herring marks offshore to the west and North of Tory Island, however, most of these marks were horse mackerel (Appendix 3c) in this area. Consequently, the distribution of NASC values is dominated by two values in particular (Lough Swilly and Donegal Bay – Figure 10).

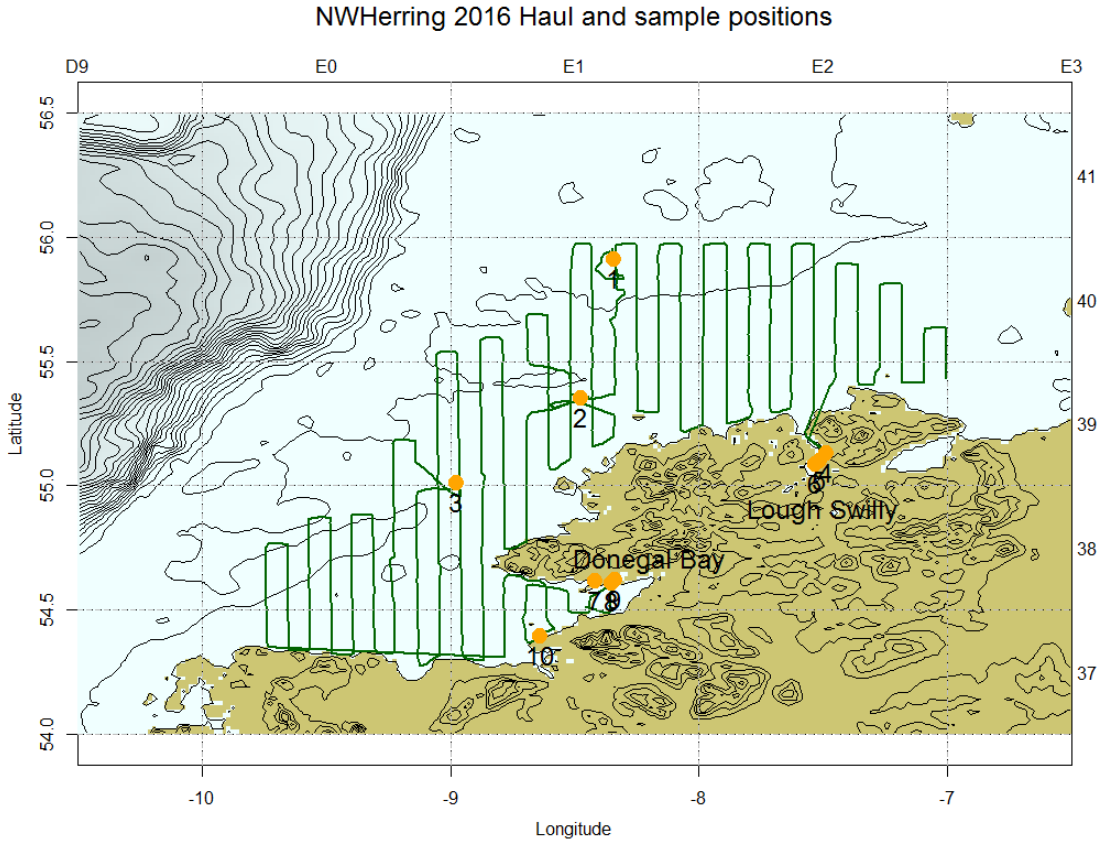


Figure 8. 6aS/7bc industry acoustic survey in 2016: distribution of biological samples and acoustic transect data in 6aS - all samples and acoustics.

Length frequency

The length frequency distributions of herring in the hauls/samples is shown in Figure 9. Strong modes were evident in most of the samples, and in these cases, the majority of fish were > 24 cm. Hauls 1 (offshore) and 4 (Inver Bay) had a broader distribution of herring in the sample. The samples were dominated by mature fish (Table 5), expected in fish captured close to areas and times where spawning is known to occur during this time (Table 1). Horse mackerel NASC was more evenly distributed throughout the survey area, but particularly throughout the area west of Tory Island (Figure 11). Horse mackerel were dominated by 21 – 23 cm fish (Figure 12).

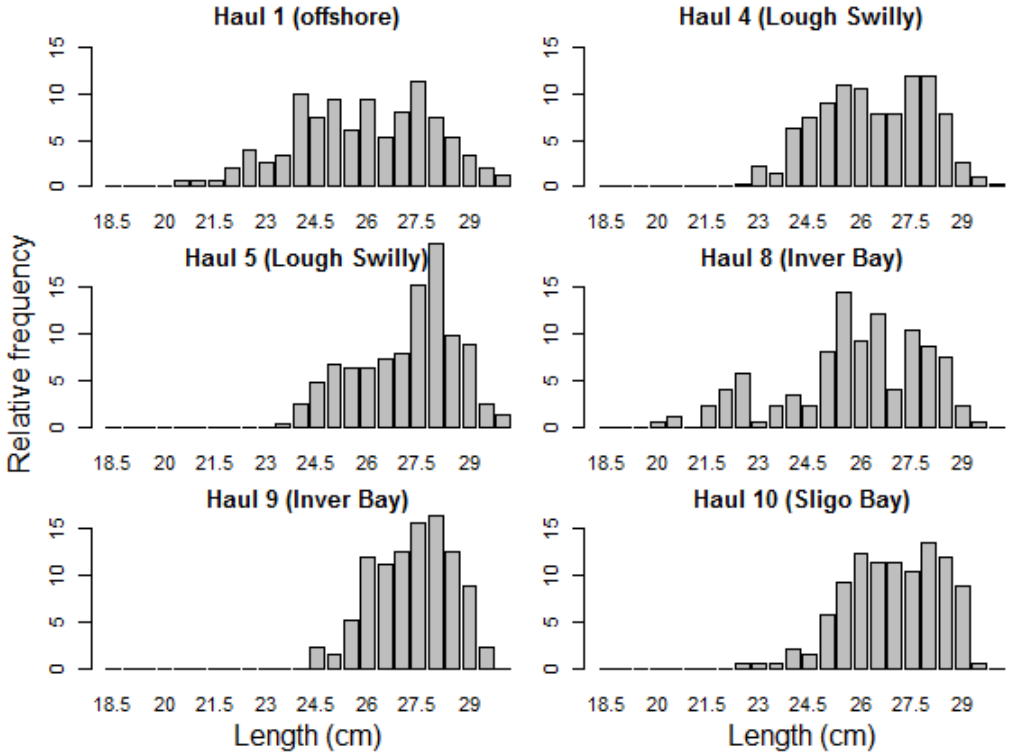


Figure 9. 6aS/7bc industry acoustic survey in 2016: length (cm) frequency distributions of herring in each haul.

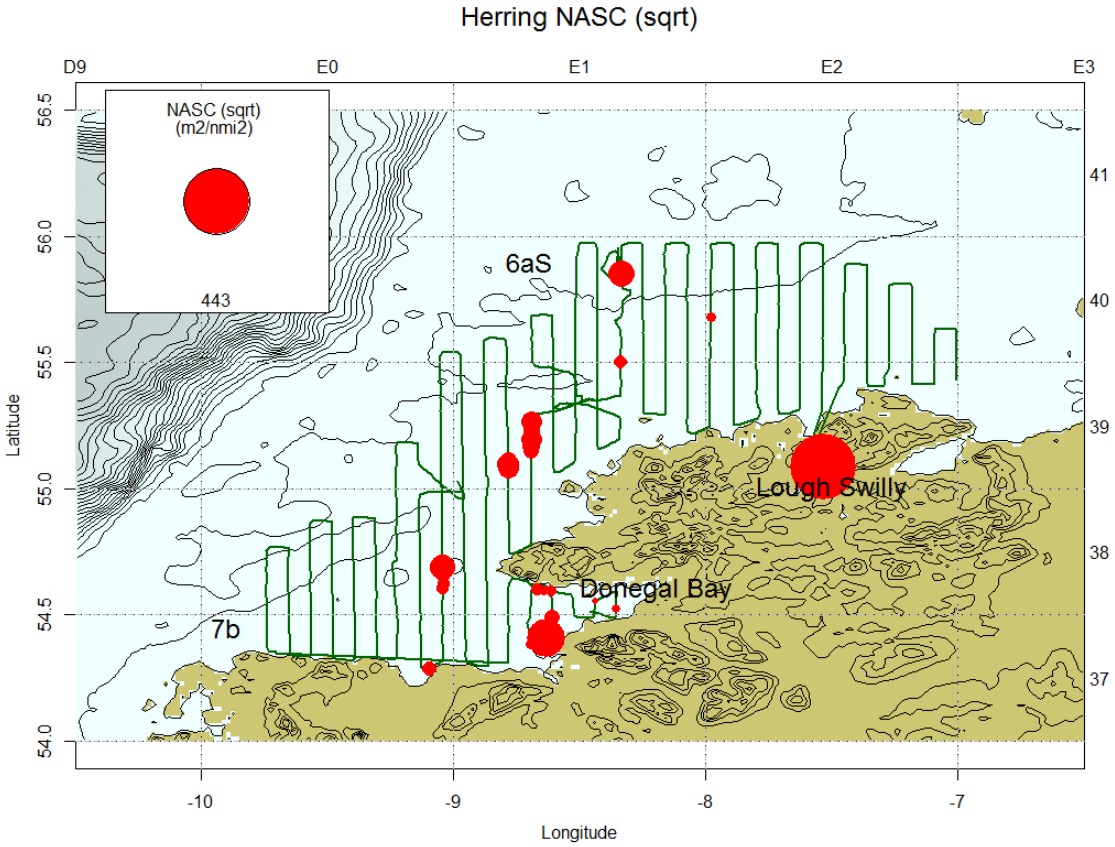


Figure 10. 6aS/7bc industry acoustic survey in 2016: √NASC of herring.

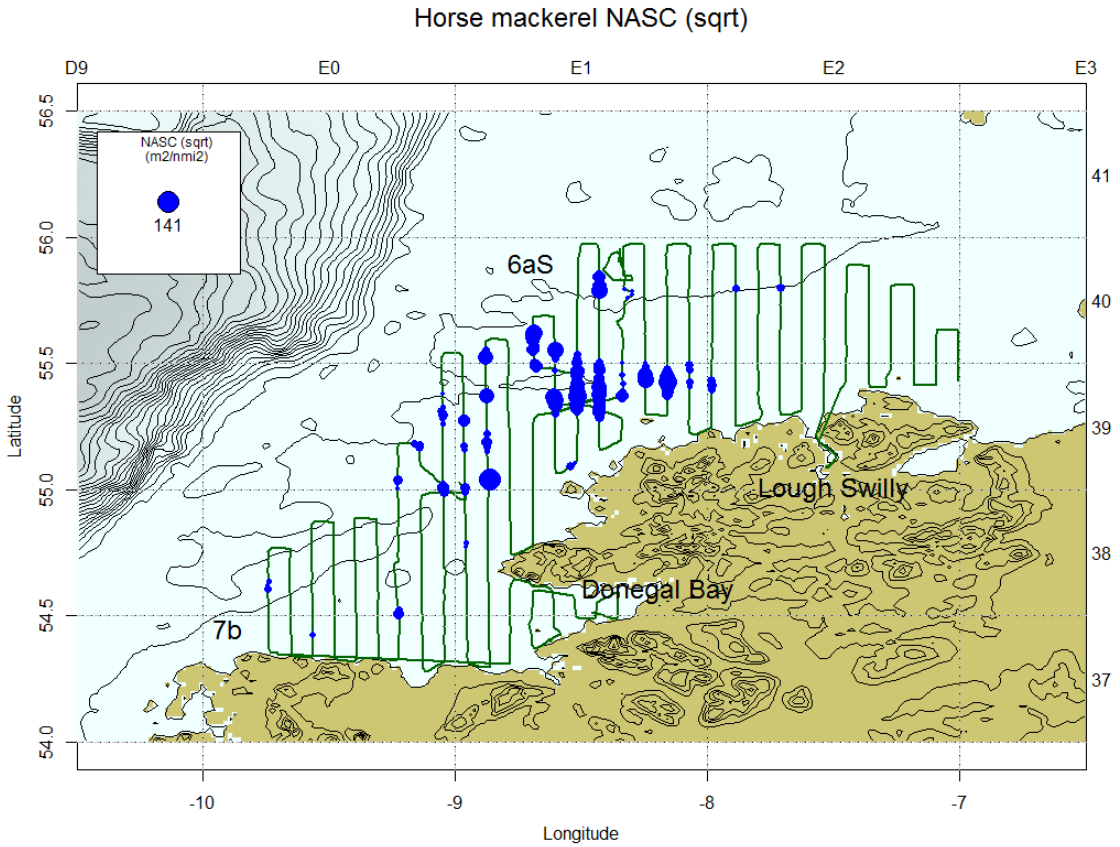


Figure 11. 6aS/7bc industry acoustic survey in 2016: √NASC of horse mackerel.

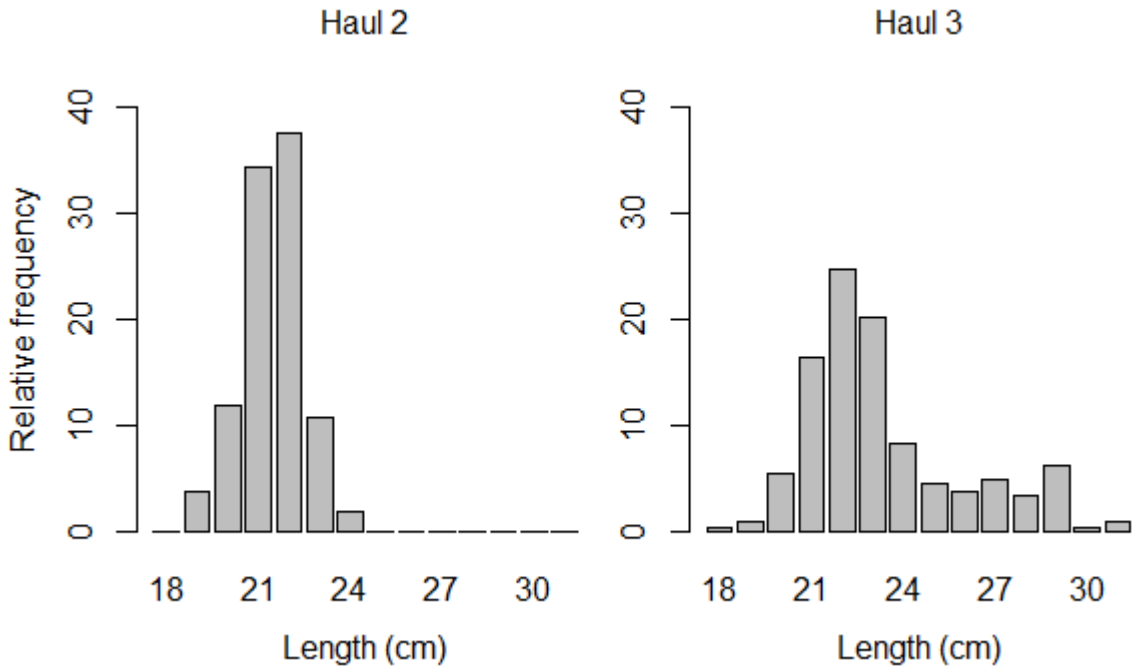


Figure 12. 6aS/7bc industry acoustic survey in 2016: length (cm) frequency distributions of horse mackerel in hauls 2 and 3.

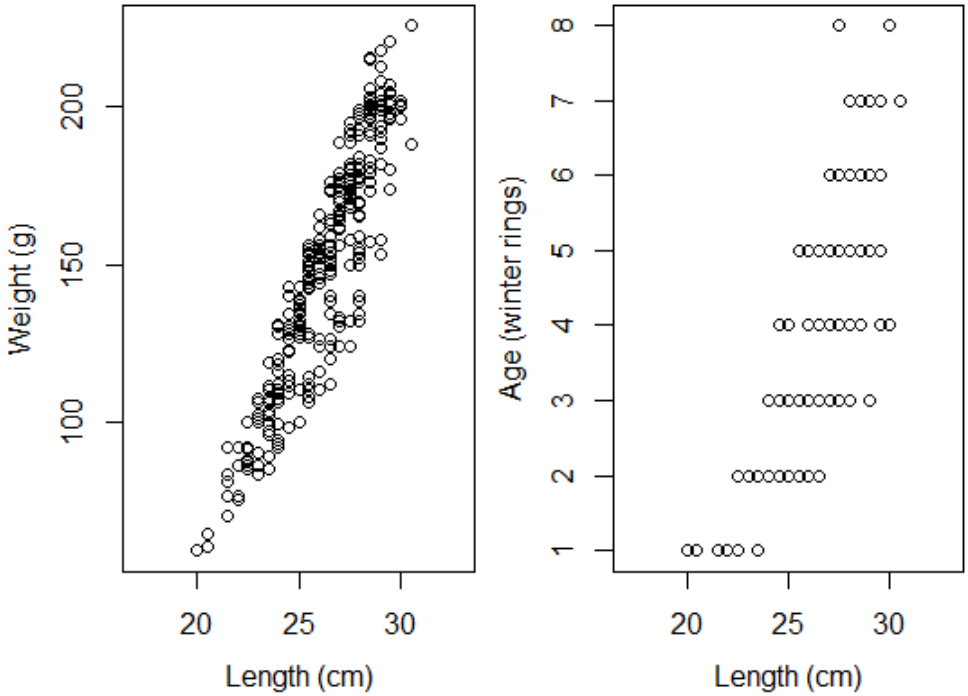


Figure 13. 6aS/7bc industry acoustic survey in 2016: weight at length and age at length of herring.

Maturity

Maturity at age for 6aS/7bc herring is shown in Table 5. 74% of 1-wr herring were immature, and 0.02% of 2-wr herring were immature.

Table 5. 6aS/7bc industry acoustic survey in 2016: maturity at age for 6aS/7bc herring in 2016.

Age (winter rings)	Immature	Mature
1	74%	26%
2	0.02%	99.98%
3+	0%	100%

Biomass and abundance

The estimated total stock biomass (TSB), number at age, numbers at length class and mean weight of herring found in each of the survey areas is shown in Tables 6 - 8. The transects in Lough Swilly were executed in a zig-zag pattern due to the shallow nature of the habitat, therefore for estimation purposes, Lough Swilly was treated as a separate strata within StoX. The entire survey area outside of Lough Swilly was treated as two stratum; NW and Donegal Bay (parallel transects with 3nmi spacing). The combined estimated numbers at age and biomass at age over the entire survey area is also shown in Table 9. The TSB estimate for the combined 6aS/7bc area was 35,475 tonnes (Lough Swilly = 9,411 tonnes, Donegal Bay = 13,301 tonnes, and the remaining NW area = 12,762 tonnes).

Table 6. 6aS/7bc industry acoustic survey in 2016: age-disaggregated estimate of mature herring in survey Lough Swilly area. The estimated TSB for the Lough Swilly strata = 9,411 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: Swilly
SpecCat: Clupea herangus

	age									
LenGrp	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	-	-	-	-	-	-	-	-	-
22.0-22.5	-	-	-	-	-	-	-	-	-	-
22.5-23.0	174	-	-	-	-	-	-	174	15.8	91.00
23.0-23.5	955	-	-	-	-	-	-	955	99.3	104.00
23.5-24.0	913	-	-	-	-	-	-	913	100.1	109.60
24.0-24.5	3002	-	-	-	-	-	-	3002	334.7	111.50
24.5-25.0	1904	1142	762	-	-	-	-	3808	467.8	122.85
25.0-25.5	2200	1818	574	-	-	-	-	4592	621.8	135.42
25.5-26.0	1135	2931	-	851	-	-	-	4917	711.6	144.73
26.0-26.5	1136	2178	1515	-	-	-	-	4830	715.1	148.06
26.5-27.0	-	2413	1062	965	-	-	-	4441	684.7	154.20
27.0-27.5	-	1258	1355	1258	678	-	-	4550	765.2	168.19
27.5-28.0	-	3131	-	4011	-	-	-	7142	1258.7	176.23
28.0-28.5	-	-	-	4657	2873	594	-	8125	1440.8	177.33
28.5-29.0	-	-	686	1274	1470	1470	-	4900	975.7	199.14
29.0-29.5	-	203	-	2741	609	-	-	3553	692.9	195.03
29.5-30.0	-	-	302	302	504	504	-	1613	322.6	200.06
30.0-30.5	-	-	207	-	-	-	621	829	165.6	199.88
30.5-31.0	-	-	-	-	-	174	-	174	39.2	226.00
TSN(1000)	11418	15075	6463	16060	6134	2742	621	58514	-	-
TSB(1000 kg)	1412.5	2333.1	1008.9	2868.7	1118.5	546.2	123.8	-	9411.7	-
Mean length (cm)	24.48	26.18	26.58	27.81	28.23	28.70	30.00	-	-	-
Mean weight (g)	123.70	154.77	156.09	178.62	182.35	199.20	199.17	-	-	160.84

Table 7. 6aS/7bc industry acoustic survey in 2016: age-disaggregated estimate of mature herring in survey Northwest area. The estimated TSB for the Northwest strata = 12,762 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: NW
SpecCat: Clupea herangus

	age										
LenGrp	1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	110	-	-	-	-	-	-	-	110	6.5	59.00
20.5-21.0	289	-	-	-	-	-	-	-	289	18.0	62.40
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	578	-	-	-	-	-	-	-	578	46.7	80.90
22.0-22.5	730	-	-	-	-	-	-	-	730	59.9	82.15
22.5-23.0	623	736	-	-	-	-	-	-	1359	121.6	89.50
23.0-23.5	-	1349	-	-	-	-	-	-	1349	132.3	98.04
23.5-24.0	162	1293	-	-	-	-	-	-	1455	149.6	102.81
24.0-24.5	-	2823	101	-	-	-	-	-	2924	323.9	110.78
24.5-25.0	-	2980	1084	163	-	-	-	-	4226	516.7	122.28
25.0-25.5	-	2522	2312	420	-	-	-	-	5254	683.9	130.18
25.5-26.0	-	2127	5016	-	327	-	-	-	7470	1036.8	138.80
26.0-26.5	-	1321	4842	880	275	-	-	-	7319	1073.6	146.70
26.5-27.0	-	225	5738	675	1069	-	-	-	7707	1166.6	151.38
27.0-27.5	-	-	2289	2345	1675	279	-	-	6589	1101.2	167.13
27.5-28.0	-	-	3039	110	4586	608	276	387	9005	1573.3	174.71
28.0-28.5	-	-	278	557	3787	4567	1058	-	10248	1765.5	172.27
28.5-29.0	-	-	-	280	1233	2971	2859	-	7343	1423.5	193.87
29.0-29.5	-	-	172	-	2234	2291	573	-	5269	1009.0	191.49
29.5-30.0	-	-	-	173	460	403	863	-	1899	377.0	198.52
30.0-30.5	-	-	-	108	-	-	-	484	592	118.1	199.45
30.5-31.0	-	-	-	-	-	-	286	-	286	58.1	203.20
TSN(1000)	2491	15375	24871	5712	15647	11119	5915	871	82000	-	-
TSB(1000 kg)	199.9	1789.3	3752.8	917.5	2789.0	2035.8	1112.8	164.8	-	12762.0	-
Mean length (cm)	21.84	24.48	26.17	26.88	27.78	28.34	28.65	28.89	-	-	-
Mean weight (g)	80.26	116.38	150.89	160.64	178.25	183.10	188.13	189.17	-	-	155.63

Table 8. 6aS/7bc industry acoustic survey in 2016: age-disaggregated estimate of mature herring in survey Donegal Bay area. The estimated TSB for the Donegal Bay strata = 13,301 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: Donegal Bay
SpecCat: Clupea herangus

	age										
LenGrp	1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	223	-	-	-	-	-	-	-	223	13.2	59.00
20.5-21.0	446	-	-	-	-	-	-	-	446	27.2	61.00
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	892	-	-	-	-	-	-	-	892	74.8	83.88
22.0-22.5	1338	-	-	-	-	-	-	-	1338	108.2	80.83
22.5-23.0	1337	557	-	-	-	-	-	-	1894	167.9	88.65
23.0-23.5	-	444	-	-	-	-	-	-	444	41.8	94.00
23.5-24.0	557	557	-	-	-	-	-	-	1114	108.7	97.60
24.0-24.5	-	1778	333	-	-	-	-	-	2112	245.9	116.42
24.5-25.0	-	1601	862	-	-	-	-	-	2463	313.5	127.30
25.0-25.5	-	1613	2535	346	-	-	-	-	4494	590.3	131.36
25.5-26.0	-	711	6993	-	-	-	-	-	7704	1098.7	142.62
26.0-26.5	-	-	8110	-	614	-	-	-	8725	1316.1	150.85
26.5-27.0	-	-	7811	-	1098	-	-	-	8910	1379.7	154.85
27.0-27.5	-	-	3512	2759	1380	-	-	-	7651	1289.7	168.57
27.5-28.0	-	-	1126	501	4756	1377	751	751	9261	1690.6	182.55
28.0-28.5	-	-	-	-	3372	4621	1748	-	9741	1787.0	183.45
28.5-29.0	-	-	-	-	1612	4091	2728	-	8431	1642.2	194.79
29.0-29.5	-	-	-	-	1257	4401	126	-	5784	1127.5	194.93
29.5-30.0	-	-	-	-	270	135	946	-	1351	278.8	206.30
TSN(1000)	4794	7262	31283	3606	14359	14625	6298	751	82978	-	-
TSB(1000 kg)	390.5	855.7	4725.6	602.7	2615.8	2768.5	1210.0	132.9	-	13301.7	-
Mean length (cm)	21.99	24.26	26.04	26.88	27.71	28.41	28.40	27.50	-	-	-
Mean weight (g)	81.46	117.84	151.06	167.16	182.17	189.30	192.11	177.00	-	-	160.31

Table 9. 6aS/7bc industry acoustic survey in 2016: age-disaggregated estimate of mature herring in total survey area. The total estimated TSB for the entire survey area = 35,475 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	333	-	-	-	-	-	-	-	333	19.7	59.00
20.5-21.0	735	-	-	-	-	-	-	-	735	45.2	61.55
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	1470	-	-	-	-	-	-	-	1470	121.6	82.71
22.0-22.5	2068	-	-	-	-	-	-	-	2068	168.1	81.30
22.5-23.0	1960	1467	-	-	-	-	-	-	3427	305.3	89.10
23.0-23.5	-	2748	-	-	-	-	-	-	2748	273.3	99.46
23.5-24.0	718	2763	-	-	-	-	-	-	3481	358.3	102.93
24.0-24.5	-	7603	434	-	-	-	-	-	8038	904.5	112.53
24.5-25.0	-	6485	3088	924	-	-	-	-	10497	1298.1	123.67
25.0-25.5	-	6335	6664	1340	-	-	-	-	14339	1896.0	132.23
25.5-26.0	-	3972	14941	-	1178	-	-	-	20091	2847.2	141.71
26.0-26.5	-	2457	15131	2396	890	-	-	-	20873	3104.8	148.75
26.5-27.0	-	225	15963	1737	3133	-	-	-	21057	3231.0	153.44
27.0-27.5	-	-	7060	6460	4313	957	-	-	18789	3156.1	167.97
27.5-28.0	-	-	7296	611	13353	1984	1027	1138	25409	4522.6	178.00
28.0-28.5	-	-	278	557	11816	12061	3401	-	28114	4993.2	177.60
28.5-29.0	-	-	-	966	4119	8532	7056	-	20673	4041.4	195.50
29.0-29.5	-	-	375	-	6232	7301	698	-	14606	2829.4	193.71
29.5-30.0	-	-	-	475	1033	1042	2313	-	4863	978.4	201.19
30.0-30.5	-	-	-	315	-	-	-	1106	1421	283.7	199.70
30.5-31.0	-	-	-	-	-	-	460	-	460	97.4	211.81
TSN(1000)	7284	34055	71229	15781	46066	31877	14956	2244	223491	-	-
TSB(1000 kg)	590.4	4057.6	10811.6	2529.1	8273.5	5922.8	2869.0	421.5	-	35475.4	-
Mean length (cm)	21.94	24.43	26.11	26.76	27.77	28.35	28.56	28.73	-	-	-
Mean weight (g)	81.05	119.15	151.79	160.27	179.60	185.80	191.84	187.87	-	-	158.73

Uncertainty

The results of the uncertainty estimates (CV) for 6aS/7bc are shown in Table 10. The CV estimates on biomass and abundance are high (~0.37) for the survey in 2016. This is most likely caused by the over-reliance on a few acoustic marks of herring in Lough Swilly and Donegal Bay in particular. Bias considerations for the survey are outlined in Table 11. Many of the considerations in Table 11 are common to all acoustic surveys and should be dealt with and reduced if possible at the survey design stage.

Table 10. 6aS/7bc industry acoustic survey in 2016: uncertainty estimates (with CV) by weight and number for the Northwest area, Lough Swilly and the total survey area.

[1] "Ton by stratum"

	Stratum	Ton.5%	Ton.50%	Ton.95%	Ton.mean	Ton.sd	Ton.cv
1:	Donegal Bay	202.739	13218.068	32029.31	12868.935	10675.991	0.8295940
2:	NW	4230.325	12282.814	22892.13	12828.311	5850.342	0.4560493
3:	Swilly	0.000	9378.993	17740.96	8386.831	6637.282	0.7913933

[1] "Total number by stratum (mill)"

	Stratum	Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
1:	Donegal Bay	1306613	82439879	210051435	82527602	70348423	0.8524230
2:	NW	26305359	78078760	146238986	82496633	37943474	0.4599397
3:	Swilly	0	56987956	113311721	52143917	41373715	0.7934524

[1] "Ton by survey"

	Ton.5%	Ton.50%	Ton.95%	Ton.mean	Ton.sd	Ton.cv
1:	14406.75	33856.86	54702.04	34084.08	12680.88	0.3720471

[1] "Total number by survey (mill)"

	Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
1:	91951196	214361102	352422737	217168152	81122699	0.3735479

Table 11. 6aS/7bc industry acoustic survey in 2016: Bias considerations

Bias Considerations	Comment
6.1 Directed movement of fish with respect to the survey tracks	No strong directed movement at this time that would make the 'flow' of herring across the strata greater than within. Pre-spawning and spawning aggregations.
6.2 Avoidance effect	unquantified
6.3 Overlapping survey layers	NA
6.4 Shallow water	Future design needs to be considered in inshore areas (e.g. Lough Swilly). Currently separate strata.
6.5 Water temperature and the propagation of the sonar beam	No problems
6.6 Quality of raw material used	Good weather throughout the survey in 2016. Good quality raw data from calibrated scientific equipment
6.7 Accuracy of calibration constant	Good calibration (results shown in Appendix 1)
6.8 Biomass species composition	Trawl information, results from monitoring fishery and acoustic expert agreement
6.9 The actual accuracy problem of acoustic surveys	Bias and sampling error – the CV as expected was high for the survey (~0.37) due to the over reliance of the estimates on relatively few herring marks

Stock Containment

There was good evidence of offshore containment in 6aS/7bc, however, stock was not contained inshore due to the hyper-aggregating behaviour and shallow distribution (<15m) in some areas. There was evidence from the fishery and the survey itself (marks on the boundaries of the survey grid at the limit of where the vessel could go) of fish inshore in areas where the survey did not cover. The over-reliance of the estimate on few areas of high herring density led to the high CV on the estimates of abundance and biomass (~0.37). There are also areas off the west Mayo and Galway coasts that are known spawning areas; these were not covered by this survey in 2016. Containment was not achieved in these areas in 2016.

4. Discussion

The Atlantic Challenge's hull mounted transducers were successfully calibrated at the pier in Killybegs. Industry/science surveys are becoming more common as a way of improving understanding of some commercial stocks (ICES 2007; Fassler et al 2011; FAO 2012; O'Donnell and Nolan 2015). Using transducers already installed is a preferred option for this type of industry collaboration survey, and therefore provides a blueprint for work on this or other industry vessels in the future in this area. Although there is a lot of good information on spawning areas of herring in 6aS, the timing of spawning is difficult to predict. Approximately 1700 miles of transects were completed, with three fishing tows completed, however, only one contained herring. Ideally more haul samples of herring would be obtained. There was evidence of very large marks of herring inshore in shallow areas, particularly in Lough Swilly and in Donegal Bay. Most of the obvious herring marks were inshore in shallow water not possible to fish with large net available to this survey. Smaller boats in the fleet were fishing in these inshore areas during the survey. There were fewer herring marks offshore, which

was also confirmed from reports coming from the fleet; herring hard to find offshore, herring only found in shallow inshore areas, and there were lots of small horse mackerel in the area. However, there was herring caught offshore in the fishery in the weeks before the survey in 2016. The high CV on the estimates of abundance and biomass was not unexpected due to the hyper-aggregating behaviour of herring observed on the survey and their shallow, inshore distribution. Also, the survey did not contain stock inshore, but most likely contained the majority of the stock offshore. The survey has particular value in relation to being a good proof of concept that industry/science partnership is a suitable way to survey this stock, including calibration of hull mounted transducers (38 and 120kHz) of the industry vessel at pier in Killybegs. The survey has provided the first data point on a new index of 6aS/7bc SSB for the surveyed area. Predicting the timing of spawning migrations and the distribution of fish on the spawning grounds is a common issue with this type of survey design. However, the ability to survey and document changes in the timing of spawning and distribution at this time of year with an industry survey is an important development. The survey provides a platform to continue work on splitting and stock ID in the greater Malin Shelf area (to be considered in an ICES working group on stock splitting [WKSIDAC 2017]), and provides information on pre-spawning behaviour in inshore areas.

5. Conclusions

The TSB estimate of 35,475 tonnes is considered to be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey. The survey in 2016 is a good example of how industry/science partnerships can work, providing a first data point to what may be a time-series of herring surveys in the 6aS/7bc area at this time of the year. There is high confidence that the herring surveyed were 6aS/7b fish due to the inshore distribution and maturity stages of the fish sampled. The survey also reflected what was experienced in the monitoring fishery at the same time. However, there are issues with the survey that need to be addressed, including:

- Stock containment; the survey did not contain the herring stock inshore due to the inshore distributions observed on the survey and reported in the fishery. The vast majority of herring marks were inshore in shallow areas that could not be fished on with the large net available. All efforts should be made to ensure good containment of the stock in the inshore areas of the survey in the future. There are also known areas off west Mayo and Galway that are known spawning areas; these were not covered by this survey in 2016. Containment was not achieved in these areas in 2016.
- The timing of the survey was an issue in 2016 – earlier timing would target herring as they migrate towards the coast and before they aggregate in inshore shallow areas. However, consideration needs to be given to the benefits of surveying early and the increased risk of stock mixing. It is reasonable to assume that fish close to the spawning ground in 6aS/7bc in winter are most likely 6aS/7bc fish. The further offshore the fish are, the more likely there is mixing occurring with stocks from further north (e.g. 6aN).
- There is a need to reduce uncertainty of estimate through better survey design and strata delineation. The CV would be reduced if schools were more widely distributed, before inshore hyper-aggregating behaviour is apparent. A design that deals with the inshore behaviour during this time could overcome this issue; including, using a smaller net from a smaller boat that can fish in shallow areas if this behaviour is evident in future
- Using samples from fishery is useful, but not ideal – more trawl samples containing herring is needed during the survey
- There is a need to develop protocols surrounding mini-surveys, particularly when large aggregations or hyper aggregating behaviour is observed (i.e. in areas like Lough Swilly)
- It is recommended that this survey from 2016 starts producing age stratified abundance estimates horse mackerel

6. References

Campbell, A. 2016. Sampling Precision in the 6.a, 7.b, and 7.c Herring Fishery. ICES CM 2016/ACOM:51. 16 pp.

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 pp

FAO. 2012. Fishing vessel execution of acoustic surveys of deep-sea species: main issues and way forward.: No. 1059.

Fassler, S. M. M., Brunel, T., Gastauer, S., and Burggraaf, D. 2013. Using acoustic data from pelagic fishing vessels to monitor pelagic fish stocks and their ecosystem. ICES C.M. 2013 / G:13.

Foote, K.G. (1987). Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987

ICES. 2007. Collection of Acoustic data from Fishing Vessels. Cooperative Research Report no. 287.

ICES. 2015a. Report of the Benchmark Workshop on West of Scotland Herring (WKWEST), 2-6 February 2015, Dublin. ICES C.M. 2015 / ACOM:34.

ICES. 2015b. Herring (Clupea harengus) in divisions VIa and VIIb,c (West of Scotland, West of Ireland). In Report of the ICES Advisory Committee, 2015. ICES Advice 2015, Book 5, Section 5.3.19.

ICES 2015c Report of the Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT) ICES CM 2015/SSGIEOM:18

ICES. 2015d. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES 2016. EU request for advice on a scientific monitoring fishery for herring in ICES divisions 6.a, 7.b, and 7.c. Section 5.4.3 in ICES Special Request Advice Celtic Seas Ecoregion. 29 April 2016.

Jolly, G. M., and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences, 47: 1282-1291.

O'Donnell, C., & Nolan, C. 2015. Boarfish Acoustic Survey Cruise Report 10 July – 31 July, 2015. FEAS Survey Series: 2015/03. Marine Institute

O'Sullivan, D., E. O'Keeffe, A. Berry, O. Tully and M. Clarke 2013. An Inventory of Irish Herring Spawning Grounds. Irish Fisheries Bulletin No. 42, 2013.

Scientific, Technical and Economic Committee for Fisheries (STECF) – 50th Plenary Meeting Report (PLEN-15-03). 2015. Publications Office of the European Union, Luxembourg, EUR 27602 EN, JRC 98672, 90 pp.

Simmonds, J., and MacLennan, D. N. 2008. Fisheries acoustics: theory and practice, John Wiley & Sons.

SIMRAD 2003. EK60 Scientific Echo Sounder System Instruction Manual. www.simrad.com

7. Appendices

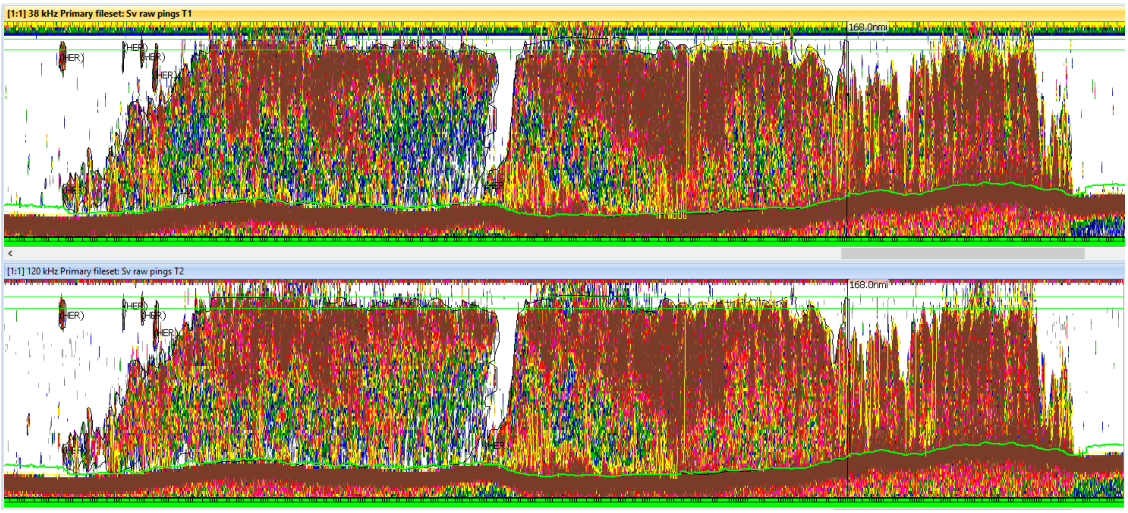
Appendix 1. 6aS/7bc industry acoustic survey in 2016: 38 kHz calibration results for Atlantic Challenge 29/11/2016

```
Calibration  Version   2.1.0.12

Date:  29.Nov.2016

Comments:
  38kHz morning 29/11/2016

Reference Target:
  TS                 -42.40 dB       Min. Distance          8.00 m
  TS Deviation         5.0 dB        Max. Distance         12.00 m

Transducer:  ES38B  Serial No.   38
  Frequency           38000 Hz       Beamtype                Split
  Gain                25.54 dB       Two Way Beam Angle    -20.6 dB
  Athw. Angle Sens.      21.90       Along. Angle Sens.       21.90
  Athw. Beam Angle    6.96 deg       Along. Beam Angle     6.89 deg
  Athw. Offset Angle  0.16 deg       Along. Offset Angle -0.09 deg
  SaCorrection        -0.67 dB       Depth                  3.00  m

Transceiver:  GPT  38 kHz 009072016d9f 1-1 ES38B
  Pulse Duration      1.024 ms       Sample Interval     0.191   m
  Power                2000  W       Receiver Bandwidth   2.43 kHz

Sounder Type:
  EK60 Version  2.2.1

TS Detection:
  Min. Value          -50.0 dB       Min. Spacing            100 %
  Max. Beam Comp.       6.0 dB       Min. Echolength          80 %
  Max. Phase Dev.          8.0       Max. Echolength         180 %

Environment:
  Absorption Coeff.   9.3 dB/km      Sound Velocity     1491.8 m/s

Beam Model results:
  Transducer Gain    = 25.69 dB      SaCorrection       = -0.67 dB
  Athw. Beam Angle   = 6.95 deg      Along. Beam Angle  = 6.95 deg
  Athw. Offset Angle = 0.11 deg      Along. Offset Angle=-0.02 deg

Data deviation from beam model:
  RMS =    0.25 dB
  Max =    2.21 dB  No. =    12  Athw. =  2.1 deg  Along =  1.5 deg
  Min =   -1.58 dB  No. =   237  Athw. =  0.7 deg  Along = -1.5 deg

Data deviation from polynomial model:
  RMS =    0.23 dB
  Max =    2.12 dB  No. =    12  Athw. =  2.1 deg  Along =  1.5 deg
  Min =   -1.52 dB  No. =   237  Athw. =  0.7 deg  Along = -1.5 deg
```

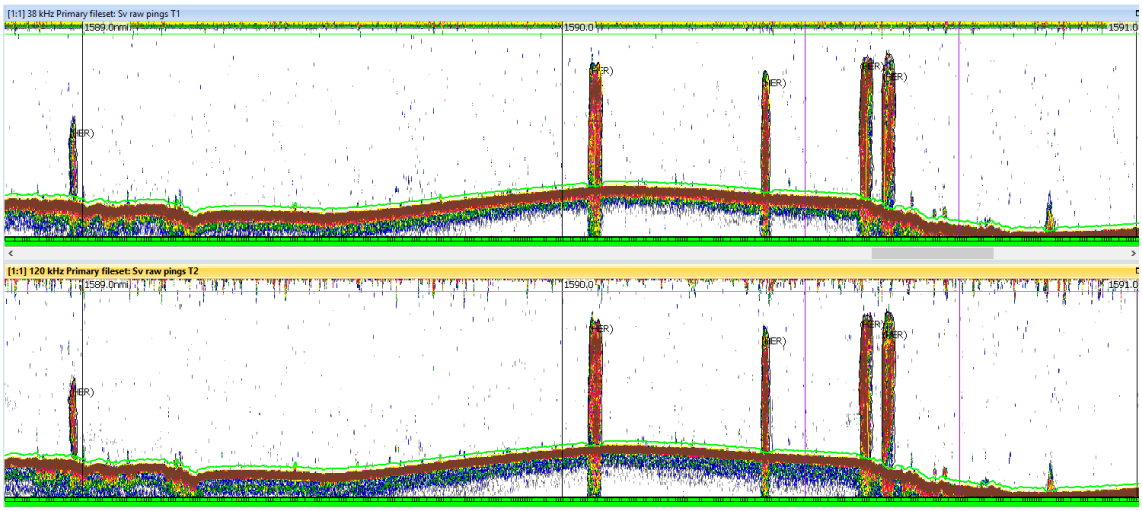
Appendix 2. 6aS/7bc industry acoustic survey in 2016: 120 kHz calibration results for Atlantic Challenge 29/11/2016

```
Calibration  Version   2.1.0.12

Date:  29.Nov.2016

Comments:
  120kHz_20161129

Reference Target:
  TS                  -39.48 dB       Min. Distance          8.00 m
  TS Deviation          5.0 dB        Max. Distance         12.00 m

Transducer:  ES120-7  Serial No.   120
  Frequency           120000 Hz       Beamtype                Split
  Gain                 25.70 dB       Two Way Beam Angle    -20.8 dB
  Athw. Angle Sens.       21.00       Along. Angle Sens.       21.00
  Athw. Beam Angle     7.10 deg       Along. Beam Angle     7.10 deg
  Athw. Offset Angle   0.00 deg       Along. Offset Angle   0.00 deg
  SaCorrection          0.00 dB       Depth                  3.00  m

Transceiver:  GPT 120 kHz 009072034686 2-1 ES120-7
  Pulse Duration       1.024 ms       Sample Interval     0.191   m
  Power                  500  W       Receiver Bandwidth   3.03 kHz

Sounder Type:
  EK60 Version  2.2.1

TS Detection:
  Min. Value           -50.0 dB       Min. Spacing            100 %
  Max. Beam Comp.        6.0 dB       Min. Echolength          80 %
  Max. Phase Dev.           8.0       Max. Echolength         180 %

Environment:
  Absorption Coeff.  35.9 dB/km       Sound Velocity     1491.8 m/s

Beam Model results:
  Transducer Gain    = 26.63 dB       SaCorrection       = -0.31 dB
  Athw. Beam Angle   = 7.10 deg       Along. Beam Angle  = 7.23 deg
  Athw. Offset Angle = 0.13 deg       Along. Offset Angle= 0.06 deg

Data deviation from beam model:
  RMS =    0.28 dB
  Max =    1.22 dB  No. =    98  Athw. = -1.5 deg  Along =  1.5 deg
  Min =   -3.04 dB  No. =   276  Athw. = -3.6 deg  Along =  3.5 deg

Data deviation from polynomial model:
  RMS =    0.24 dB
  Max =    1.08 dB  No. =    98  Athw. = -1.5 deg  Along =  1.5 deg
  Min =   -2.59 dB  No. =   276  Athw. = -3.6 deg  Along =  3.5 deg
```

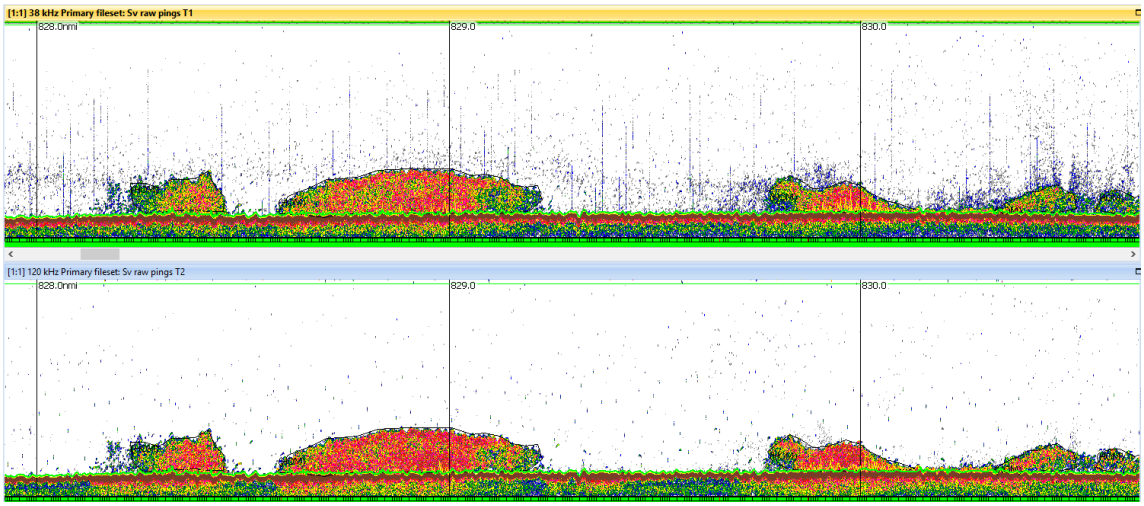
Appendix 3. 6aS/7bc industry acoustic survey in 2016: Examples of acoustic marks and their identification.



Appendix 3a. 6aS/7bc industry acoustic survey in 2016: Large herring mark in Lough Swilly, Co. Donegal (ICES area 6aS)



Appendix 3b. 6aS/7bc industry acoustic survey in 2016: Series of herring marks in Donegal Bay (ICES area 7b)



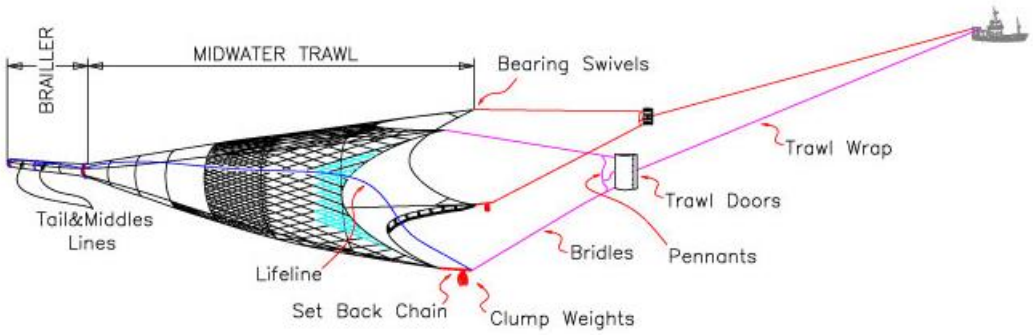
Appendix 3c. 6aS/7bc industry acoustic survey in 2016: Horse mackerel marks observed throughout Tory Bank area (ICES area 6aS)

Appendix 4. 6aS/7bc industry acoustic survey in 2016: Details of the charter vessel and net used in 2016

<u>Vessel details:</u>

Name:	MFV Atlantic Challenge
Call sign:	EI5772
Type:	Fishing vessel (Pelagic RSW)
Registered:	Dublin, Ireland
LOA:	59 m
Beam:	14.53 m
GT:	1,783 t
Net:	approximately 300m total length, 90m wing to wing, 35m average vertical mouth opening during fishing
IMO No.:	9213442
MMSI No.:	250183000

FV *Atlantic Challenge* (D642). 59m LOA



Appendix 5. 6aS/7bc industry acoustic survey in 2016: Top side monitoring station located on the bridge. Laptop (left) running Echoview and EK 60 topside PC unit (right). GPS feeds (x2) from the ship were connected via straight (patch) ethernet cables to both the SIMRAD operating computer and the MaxSea computer (not shown here). A cross-over ethernet cable linked the raw data from the SIMRAD computer to the Echoview computer for live-viewing. The entire system was powered through an Uninterrupted Power Source (UPS) to prevent data loss in the event of power outage. All data was backed up on external hard-drives after every 24 hour period.

8. Acknowledgements

We would like to express our thanks and gratitude to Stevie McSharry (Skipper) and crew of the MFV *Atlantic Challenge* for their good will and professionalism during the survey. The help and local knowledge imparted during the survey was greatly appreciated. Thanks also to the Killybegs Fishermen's Organisation (KFO), the Pelagic Freezer Trawlers Association (PFA), Scottish Pelagic Fishermen's Association (SPFA), Marine Scotland Science (Aberdeen), Raoul Kleppe at Wageningen Marine Research and Barry Electronics (Killybegs).